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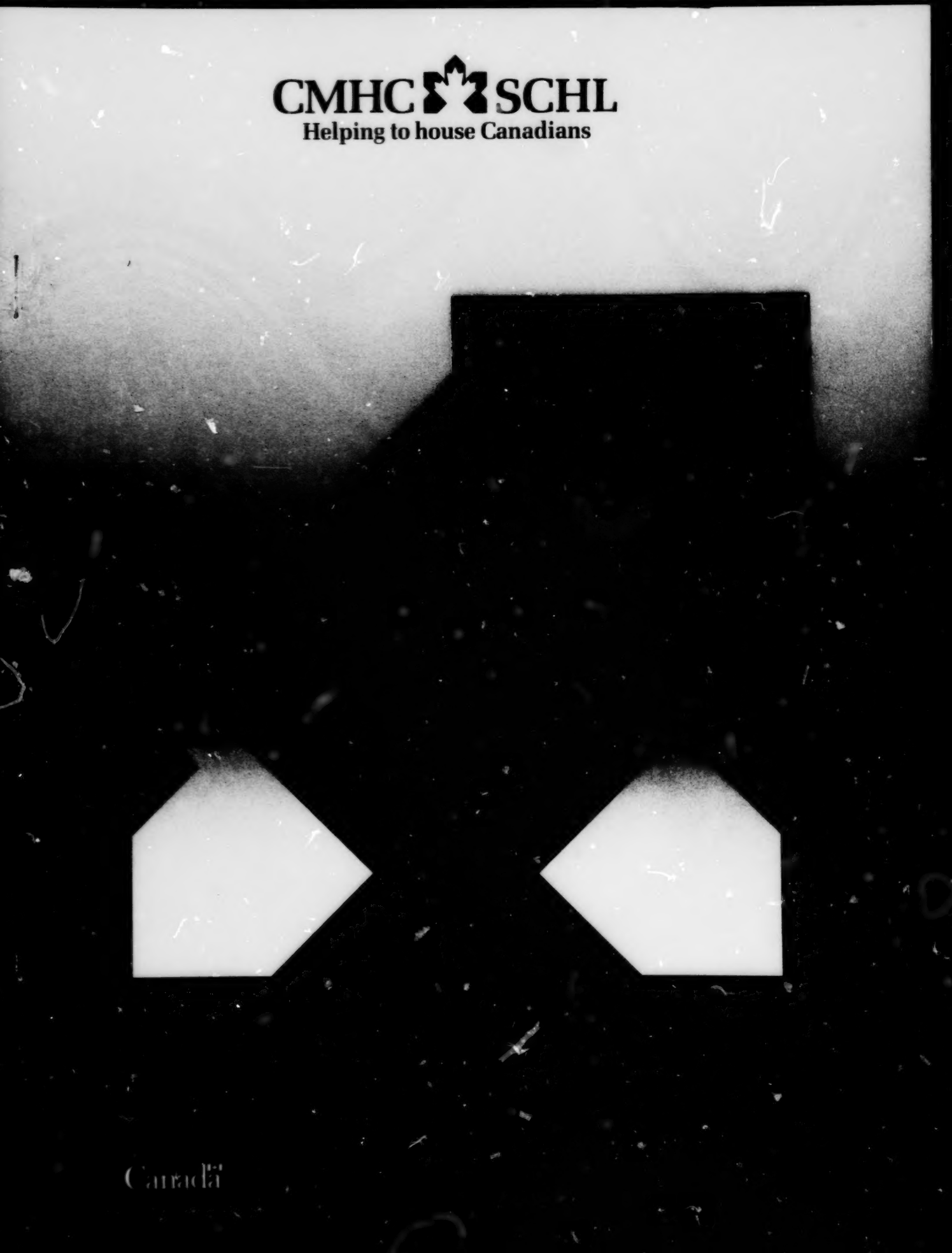

Canada

CRITERIA FOR THE TESTING OF WALL SHEATHING FOR LOAD-BEARING STEEL STUDS

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CMHC EXTERNAL RESEARCH PROGRAM

CRITERIA FOR THE TESTING OF WALL SHEATHING FOR LOAD-BEARING STEEL STUDS

March, 1990

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CMHC External Research Program

CRITERIA FOR THE TESTING OF WALL SHEATHING FOR LOAD-BEARING STEEL STUDS

March 1990

ABSTRACT

The parameters which influence the structural design of stud wall systems dependent on sheathing for bracing are best determined directly from racking tests of full scale wall panels. However small-scale tests can be substituted, giving results which are usually conservative.

The development of small-scale test criteria has been achieved., "Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels", in specification format, appears as Appendix A. The testing criteria can be used to determine or confirm sheathing parameters for use in the design of load-bearing steel stud wall systems.

A test standard, based on the criteria contained in this report, by Canadian Standards Association (CSA) or Canadian General Standards Board (CGSB) is feasible.

CMHC External Research Program

CRITERIA FOR THE TESTING OF WALL SHEATHING FOR LOAD-BEARING STEEL STUDS

March 1990

EXECUTIVE SUMMARY

Current design standards for axial load-bearing steel studs in Canada and the United States permit the carrying capacity of the studs to be influenced by the type of sheathing used. The sheathing is deemed to provide torsional and lateral restraint to each stud to which it is adequately attached. Since the steel studs are the structural components of stud wall assemblies, it is important that their load-carrying capacity be accurately estimated. The parameters which influence the structural design of stud wall systems dependent on sheathing for bracing are best determined directly from racking tests of full scale wall panels. However this is an expensive procedure, and small-scale tests can be substituted without greatly sacrificing the accuracy of the results, which are usually conservative compared with full-scale tests.

The design standards permit the use of small-scale tests "described by published, documented methods". While such methods exist, they were not available as a standardized procedure from any known source.

An external research program grant was obtained in 1989 for the development of criteria for the testing of wall sheathing for load-bearing steel studs by a team consisting of D.L. Tarlton, P.Eng., the principal investigator, Professor R.M. Schuster, P.Eng., and A.S. Zakrzewski, P.Eng. The object was to develop and document suitable criteria on the basis of knowledge that already existed. Standardization was also a major purpose since review of the literature showed wide variation in testing procedures and results. A third purpose was to justify a reduction in the number of required tests, in a given set of tests, on the basis that standardized testing criteria would result in less scatter of test results.

The development of suitable criteria for the testing of wall sheathing for load-bearing steel studs has been achieved. A sub-document entitled "Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels", in specification format, appears as Appendix A.

The testing criteria can be used to determine or confirm sheathing parameters for use in the design of load-bearing steel stud wall systems.

Consideration should now be given to the preparation of a test standard based on the criteria contained in this report by Canadian Standards Association (CSA) or Canadian General Standards Board (CGSB).

CONTENTS

1. INTRODUCTION	Page	1
2. PURPOSE OF THE PROJECT		2
3. DESCRIPTION OF THE PROJECT		3
4. CRITERIA FOR CONDUCTING AND RECORDING SMALL-SCALE TESTS OF STEEL STUD WALL PANELS		5
5. COMMENTARY ON THE CRITERIA		5
6. DESIGN VALUES		6
7. CONCLUSIONS		7
REFERENCES		8
APPENDIX A CRITERIA FOR CONDUCTING AND RECORDING SMALL SCALE TESTS OF STEEL STUD WALL PANELS		A1 - A11
APPENDIX B CLAUSE 6.8 WALL STUDS CAN/CSA S136 - M89		B1 - B5

CRITERIA FOR THE TESTING OF WALL SHEATHING FOR LOAD-BEARING STEEL STUDS

1. INTRODUCTION

In recent years, lightweight steel framing systems consisting of studs, purlins, rafters, joists and other components have been designed and constructed with varying degrees of success.[6] Wall assemblies are the most prevalent form of lightweight steel framing and proper criteria for their design are essential.

Unless fully braced by a complete bridging system, axial load-bearing steel studs, which may be C,I or Z shapes, depend on the sheathing attached to them to prevent lateral-torsional buckling. Even transverse load-bearing steel studs (e.g. wind bearing), not subject to axial load, depend on the sheathing to provide lateral support to the stud flanges in compression due to bending. As might be expected if either the sheathing or its connection to a stud is inadequate, the ability of the stud to support load will be severely compromised. It is essential therefore that designers who wish to utilize the sheathing to brace the stud, have reliable information about the properties of the sheathing which are essential to the bracing function.

Load-bearing steel studs as defined by CAN/CGSB 7.1[4] are channel or C-sections with perimeter dimensions akin to those of their wooden counterparts. Since the C-section is relatively weak in the direction normal to its web, and subject to twisting unless loaded through its shear centre (an improbability), the CSA standard which covers the design aspects, CAN/CSA S136-M89,[5] stipulates that the compressive resistance of a stud which depends on the sheathing to provide adequate lateral and rotational support will depend on a number of conditions being fulfilled. Among these is the requirement that the sheathing be connected to the top and bottom members of the wall assembly as well as to the studs, and that the sheathing retain adequate strength and stiffness for the expected

service life of the wall. Three possible failure modes for the studs are identified and provided for. Provision 1 is for compression buckling between sheathing fasteners on the assumption that every other fastener is missing or is considered ineffective. Provision 2 provides expressions to preclude overall column buckling of the wall assembly. Essential to these expressions is the magnitude of the shear rigidity of the sheathing. Provision 3 is a compatibility check of the sheathing to ensure that the sheathing has sufficient distortion capacity. It involves a comparison between the calculated shear strain and the limit shear strain of the sheathing.

From the above it is apparent that the designer must know both the limit shear rigidity and the limit shear strain of the sheathing material he elects to use. These values may be obtained with reasonable accuracy from small scale tests, following the criteria set forth herein.

2. PURPOSE OF THE PROJECT

The project had, as its primary purpose, the development and documentation of criteria for the testing of wall sheathing for load-bearing steel studs. Since parameters used in design such as the limit shear rigidity and limit shear strain of sheathing materials are derived empirically from tests and since the design standards for load-bearing steel studs in both Canada and the United States refer specifically to the use of small-scale tests "described by published, documented methods" which were not available as a standardized procedure from any known source, the compilation of a comprehensive set of criteria was considered a worthy candidate for a grant under the CMHC External Research Program.

The standardization of testing criteria was therefore a second purpose since review of the literature showed wide variations in testing procedures and results. Inasmuch as confidence must be placed on the results of tests, it was considered essential that the test procedure be such that results would be reproducible in different test facilities at different times. In other words, possible differences in tested values

because of variations in the methods of test would be minimized through standardization.

A third purpose of the project was to justify a reduction in the number of required tests in a given set from the recommended five to three on the basis that the proposed criteria would result in less scatter of test results.

3. DESCRIPTION OF THE PROJECT

A preliminary proposal was submitted to CMHC in June 1988 by Mr. D.L. Tarlton of the Canadian Sheet Steel Building Institute (CSSBI), the national organization representing the structural sheet steel industry, including manufacturers of load-bearing steel studs. A formal proposal was submitted in the fall of 1988 and was subsequently recommended for a research grant with a scheduled commencement date of April 1, 1989. The research team consisted of Professor R.M. Schuster, P. Eng. University of Waterloo, Waterloo, Ontario; Mr. A.S. Zakrzewski, P. Eng., Willowdale, Ontario; and Mr. D.L. Tarlton, P. Eng., Canadian Sheet Steel Building Institute, Willowdale, Ontario. Professor Schuster and Mr. Zakrzewski had prior experience with, and considerable expertise in, the design and testing of load-bearing steel stud wall assemblies. Mr. Tarlton contributed his general experience with lightweight steel framing systems and acted as project manager.

A series of meetings were convened to assess available information, determine the approach to be taken, assign specific tasks and review progress. The project team agreed that the development and documentation of criteria for conducting and recording small-scale tests of steel stud wall panels was the most beneficial approach, since the tests were relatively inexpensive; test results, compared with those of full scale tests,[2] were conservative; and reproducibility of test results obtained from different facilities could be maintained by standardizing the test and requiring careful control of the fabrication and assembly of test specimens.

A visit was made to a plant manufacturing gypsum wallboard, widely used as sheathing material, notwithstanding the fact that it is a frangible product in its normal, dry state and considerably weakened when it is wet. (Those detriments tend to be offset by low cost, ready availability, easy installation and good performance in fire situations.) The purpose of the visit was to update the project team members on the manufacturing process, to determine the types of gypsum board currently being marketed, including any important differences, and to arrange for samples to be sent to the Structures Laboratory at the University of Waterloo for testing. The objectives of the project team were fulfilled and some useful cooperation and goodwill were gained.

At the Structures Laboratory, a series of simple tests in which a 300 mm square piece of gypsum board was attached at one corner by a single screw to a short length of steel stud, and then pulled until failure occurred, was subsequently carried out. It was thought that values obtained from such tests might obviate the need for the small-scale racking test as described in Appendix A. However, correlation with previously-performed racking tests was not positive and the effort was abandoned. (It is possible that a better-controlled test would have shown better correlation and this might be tried at a future date.) The tests that were performed did, however, serve to confirm the substantial loss of strength due to wetting. Whereas dry gypsum board specimens subjected to a tensile load failed first by cracking of the gypsum and eventually by fracture of the outer plies of paper, the saturated specimens failed completely as soon as the gypsum cracked, the wet paper plies having virtually no resistance to applied load.

At the time the project was begun, it had become apparent that the design procedure promulgated in both Canada and the United States for load-bearing studs braced by sheathing was in error in certain respects. A full scale test at Cornell University confirmed what several individuals had suspected, that wider spacing between studs did not, for a given wallboard and method of attachment, increase the carrying capacity of the

stud. Subsequently, both American and Canadian design specifications are scheduled for revision so as to require the same sheathing shear rigidity values for any steel stud spacing between 300 and 600 mm.

With the design specifications clarified, the work under this project was carried to completion. The result is the document which forms the major part of this report, entitled "Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels".

4. CRITERIA FOR CONDUCTING AND RECORDING SMALL-SCALE TESTS OF STEEL STUD WALL PANELS

This section has been prepared in specification format in order that it may be excerpted from the report with minimum effort and is located in Appendix A.

5. COMMENTARY ON THE CRITERIA

Comments on certain parts of the Criteria contained in Appendix A are provided for information purposes. Numbers refer to the Clause numbers of the Criteria.

1.4 For a particular application a specific sheathing may need to be assessed for fire resistance, flame spread, durability, ease of installation, cost, and availability, in addition to the properties determined by small-scale racking tests.

4.3.2 The size of the steel stud (and track) should be kept the same for every test if comparative test results are required.

4.6 The requirement of a template to locate the position of screw holes and the requirement that pilot holes be drilled in each sheathing element is aimed at eliminating as many unintentional variables from the testing as possible. Screws are not placed nor driven with the same degree of precision in the field and it might be argued that this should be taken

into account when establishing design values from test results. However, because of the size factor, actual lightweight steel framed wall assemblies usually are such that a corner failure due to racking would not cause as much loss of capacity as would be the case with a similar occurrence in a small-scale test. Also, a study[3] sponsored by American Iron and Steel Institute (AISI) in 1988, to determine the relationship between the number and distribution of sheathing fasteners and the shear rigidity of the wall assembly, showed that the shear rigidity of various wall sizes can be predicted from 600 x 600 mm specimens for any configuration of fasteners. Thus it seems reasonable to take the values obtained by test as being valid for design purposes and representative of the values that would relate to actual construction.

6. DESIGN VALUES

In order to be compatible with the values for limit shear rigidity and limit shear strain given in Table 6, Sheathing Parameters, of CAN/CSA S136-M89, the value of the shear rigidity q from tests can be converted to $\bar{q}_o$, the limit shear rigidity when the fasteners are spaced 300 mm on centre. The correcting formula is $\bar{q}_o = q/(2-s/300)$ where s is the fastener spacing.

Thus for the test specimens, with fasteners spaced 255 mm on centre,

$$\bar{q}_o = q/(2-255/300)$$
$$\bar{q}_o = 0.87q$$

The value of $\bar{\gamma}_o$ the limit shear strain based on the limit shear rigidity q_o is 1/0.87 or 1.15 times the shear strain γ derived from the small scale tests.

Thus $\bar{\gamma}_o = 1.15\,\gamma$

The values currently (1990) appearing in Table 6 of CAN/CSA S136 were derived from previous small-scale tests using shear rigidities that corresponded to the deflection at a load of 0.8 of the ultimate test load.[1]

7. CONCLUSIONS

7.1 The main purpose of this project, the development of suitable criteria for the testing of wall sheathing for load-bearing steel studs has been achieved. The result is a sub-document entitled "Criteria for Conducting and Recording Small-Scale Tests of Steel Stud Wall Panels" prepared in specification format as Appendix A so that it may be readily excerpted from the body of the report.

7.2 The authors believe that the testing criteria as defined can be put to immediate use to determine or confirm sheathing parameters that are not currently tabulated for use in the design of load-bearing steel stud wall systems.

7.3 In order to have wider recognition and availability of the testing criteria, consideration should be given to the preparation of a test standard based on the criteria contained in this report, and formulated under the aegis of an accredited standards writing organization such as Canadian Standards Association (CSA) or Canadian General Standards Board (CGSB). In the interim, and with CMHC agreement, Canadian Sheet Steel Building Institute (CSSBI) could be requested to publish the testing criteria as a service to designers, manufacturers, contractors and other interested parties.

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4. **"Cold Formed Steel Framing Components"**, CAN/CGSB 7.1-1986, Canadian General Standards Board, Ottawa, ON, 1986

5. **"Cold Formed Steel Structural Members"**, CAN/CSA S136-M89, Canadian Standards Association, Rexdale, ON, 1990

6. **"Lightweight Steel Framing Manual"**, Canadian Sheet Steel Building Institute, Willowdale, ON, 1987

APPENDIX A

CRITERIA FOR CONDUCTING AND RECORDING SMALL-SCALE TESTS OF STEEL STUD WALL PANELS

1. PURPOSE AND SCOPE

1.1 - The criteria given herein for conducting and recording small-scale tests of steel stud wall panels are intended to provide the basis for assessing the ability of sheathing and its attachments to provide lateral and torsional stability to steel studs which are required, in service, to resist axial load, with or without transverse load.

1.2 - Test values obtained in accordance with these criteria are valid for design application only where the specified framing members, sheathing, and attachments are essentially similar to those used in the test program from which the test values were obtained.

1.3 - Where test values obtained in accordance with these criteria would not be valid for design application because of the intended configuration, assembly, loading or use of a steel stud wall panel in service, tests shall be performed and evaluated in accordance with ASTM Standard E564 or in accordance with another recognized procedure prescribed by, or acceptable to, the authority having jurisdiction.

1.4 - The suitability of a specific sheathing material for a particular application may be dependent on environmental or other factors which must be taken into consideration in addition to test results obtained in accordance with these criteria.

2. REFERENCE DOCUMENTS

2.1 **ASTM C954** - Steel Drill Screws for the Application of Gypsum Board or Metal Plaster Bases to Steel Studs From 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness (1986)
C1007 - Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories (1983)
E72 - Methods of Conducting Strength Tests of Panels for Building Construction (1980)
E564 - Method of Static Load Test for Shear Resistance of Framed Walls for Buildings (1976)

2.2 **CGSB CAN/CGSB 7.1** - Cold Formed Steel Framing Components, (1986)

2.3 **CSA CAN/CSA S136** - Cold Formed Steel Structural Members (1989)

3. SUMMARY OF METHOD

The shear strength, shear rigidity and shear strain of a set of test specimens are determined by racking each specimen from a rectangle to a parallelogram. This is accomplished by anchoring the bottom edge of the specimen to the test fixture and applying a load perpendicular to the vertical edge of the specimen near the top. The specimen is allowed to distort in its own plane. The applied loads and corresponding deflections are measured. In a cyclic load test, opposing loads are applied at each vertical edge in a defined sequence.

4. TEST SPECIMENS

4.1 GENERAL

Test specimens shall be constructed in accordance with Figure 1 and the requirements of Clause 4.

4.2 SHEATHING

4.2.1 - The type of sheathing, including the brand name, the manufacturer and all pertinent product information shall be recorded prior to testing.

4.2.2 - Thickness shall be determined as the average of four measurements taken around the perimeter of each sheathing element in a test specimen. Sheathing thickness shall be representative of that used in actual construction.

4.2.3 - The height and width dimensions of a sheathing element shall be 610 mm (+3 -0).

4.2.4 - All edges shall be cleanly cut. Taped or finished edges, as on uncut sheets of gypsum board, shall not be permitted.

4.2.5 - Care shall be exercised to avoid damage to sheathing elements, particularly their corners, when assembling and installing test specimens.

4.3 STEEL STUDS

4.3.1 - Steel studs shall conform to CAN/CGSB-7.1 and shall have no cut-outs.

4.3.2 - Steel studs shall have a depth of 92 mm, a flange width of 41 mm, a thickness of 1.2 mm and be 603 mm (+0 -3) in length.

4.4 STEEL TRACK

Steel track shall conform to CAN/CGSB 7.1 and shall have a depth compatible with the steel studs, a minimum width of 30 mm and a thickness of 1.2 mm. The upper track shall be 610mm (+0 -3) in length. The lower track shall be 710 mm (+5 -0) in length.

4.5 STEEL SCREWS

4.5.1 - Steel screws shall conform to ASTM C954. Penetration beyond joined materials shall be not less than 3 exposed threads.

4.5.2 - Studs shall be connected to the tracks with one 10-16 x $\frac{1}{2}$ inch Phillips Low Profile Pan Head screw at each corner on each track flange, (a total of eight fasteners per test specimen).

4.5.3 - Sheathing shall be connected to the studs and tracks with the same type of fastener to be used in actual construction. If not otherwise specified, gypsum board shall be connected with 6-20 Phillips Bugle Head screws; fibreboard or plywood shall be connected with 8-18 Phillips Trumpet Head screws; cementitious board shall be connected with 8-18 Phillips Wafer Head screws. A total of 16 fasteners per test specimen are required.

4.6 ASSEMBLY OF TEST SPECIMENS (Figure 1)

4.6.1 - A template shall be used to locate the position of the screw holes on the outside face of each sheathing element. See Figure 1.

4.6.2 - Holes shall be accurately drilled through each sheathing element to permit entry of a screw connector. The hole diameter shall match the screw size.

4.6.3 - The track/stud frame shall be assembled using a jig to ensure accuracy. Dimensions given in Figure 1 are exact, unless noted.

4.6.4 - Each sheathing element shall be fastened to the track/stud frame with carefully driven fasteners inserted in the pre-drilled holes of the sheathing. Fasteners shall be secure but not overtightened.

5. LOADING SYSTEM AND INSTRUMENTATION (Figure 2)

5.1 - Unidirectional shear load shall be provided by a hydraulic jack attached to an upright of the test fixture. Cyclic loading requires a second hydraulic jack attached to the other upright of the test fixture so as to provide shear load in the opposite direction. Each jack shall be powered by a separate pump.

5.2 - The maximum force to be exerted by the hydraulic jack depends on factors such as the type of sheathing, its condition (e.g. wet or dry), and the size of sheathing screws. For the majority of cases, a hydraulic jack and its pump shall be capable of exerting a load of at least 7.5 kN. A load cell connected to each hydraulic jack shall be calibrated to at least 10 kN.

5.3 - A digital strain indicator connected to the load cell by means of a switch-and-balance unit is recommended. The read-out accuracy shall be plus or minus 5 N.

5.4 - Dial indicators* with an accuracy of plus or minus 0.02 mm are recommended for the measurement of deflections. For a static load test (unidirectional load) two dial indicators are required. One indicator, located near the top of the specimen, is used to measure deflection. The second indicator, located at the bottom, is used to determine whether the specimen moves relative to the base of the test fixture. In cyclic load tests two additional dial indicators are required, at the opposite end of the test specimen.

* or any other deformation measurement system.

6. TEST PROCEDURE

6.1 GENERAL

6.1.1 - Prior to testing, assembled specimens not intended for high humidity or water immersion tests in accordance with Clause 6.4 shall be kept for at least 24 hours at a temperature of 22°C (+2 -2) and 40% (+2 -3) relative humidity.

Note: Deviation of relative humidity beyond 2 percent can affect shear rigidity. For example, for wafer board or gypsum board sheathing, a 5 percent increase in relative humidity reduces the shear rigidity by approximately 3 percent, while a 5 percent decrease in relative humidity increases the shear rigidity by approximately the same amount.

6.1.2 - Test specimens shall be examined prior to installation in the test fixture. Cracks, damaged corners, or surfaces excessively damaged by screw heads will affect test results and specimens exhibiting same shall be rejected or refurbished.

6.1.3 - When the test specimen is secured in the test fixture, the dimensions c, d, h and j as defined in Figure 3 shall be recorded to the nearest millimetre. The dimensions c and d are the average of measurements taken at each set of screws (3 sets on each side of the specimen, totaling 6). All dimensions shall be measured from the underside of the lower track.

6.1.4 - In cyclic tests, the dimensions h and j shall be determined for the instrumentation at each end of the specimen and each end must be positively identified (e.g. "East" and "West", etc.)

6.1.5 - Testing shall be performed at a temperature of 22°C (+2 -2) and relative humidity of 40% (+2 -2).

6.1.6 - Dial indicators and digital strain indicators shall be set to zero prior to testing.

6.1.7 - A load equal to approximately 8 percent of the expected failure load shall be applied, the deflection recorded and load then removed. After a 1 minute interval, reset all dials and strain indicators to zero. For the cyclic load test, the procedure shall be repeated in the opposite direction.

Note: If the expected failure load is not known, a trial run to obtain an indication of the failure load and the corresponding deflection is recommeded.

6.2 STATIC TEST

6.2.1 - Three identical specimens shall be tested. If the value of a result in any of the three tests deviates by more than 10 percent from the average values obtained from the three tests, a fourth test shall be performed and the average values from all four tests shall be determined.

6.2.2 - Should a premature failure occur due to an unusual weakness of the test specimen resulting from undetected damage, incorrectly driven screws, etc. the test shall be invalidated and repeated using another specimen. The test report shall record any such occurrence.

6.2.3 - Apply load in increments as follows:

(a) eight increments equal to 10 percent of the estimated failure load at 30 to 40 second intervals

(b) two increments equal to 5 percent of the estimated failure load

(c) further increments equal to 3.5 percent of the estimated failure load until failure occurs

6.2.4 - Beginning with the ninth load increment read and record load and deflection twice, the second time two minutes after the first reading. Maintain the load at a constant value.

6.2.5 - After each load increase:

(a) record the value of the load and the corresponding deflection

(b) visually inspect the test specimen on each side, particularly at each corner, and record the occurrence and location of any cracks, tears, sheathing deformations or other distress.

6.2.6 - The failure load shall be the maximum load that can be sustained by the specimen. When the behaviour of the specimen under load indicates that the specimen might fail suddenly and damage the deformation-measuring apparatus, that apparatus shall be removed and the load increased continually until the maximum load that can be applied to the specimen is determined.

6.2.7 - After failure has occurred, the load shall be decreased to zero and the deflection measured after 2 minutes. The mode of failure and condition of the test specimen shall be recorded.

6.3 CYCLIC TEST

6.3.1 - Load shall be applied and raised in increments as follows:

(a) one increment equal to 20 percent of the estimated failure load

(b) four increments equal to 15 percent of the estimated failure load

The highest load applied will therefore be 0.8 of the estimated failure load

6.3.2 - For each load increment there shall be five load cycles, as follows:

(a) load the specimen to the required value at a rate of approximately 1000 N/min

(b) record the actual load and corresponding deflection

(c) visually inspect each corner of the test specimen on each side and record the occurence and location of any cracks, tears, deformations or other distress

(d) reduce the load to zero, record the deflection and immediately apply an equal load in the opposite direction as in (a) above.
(e) repeat steps (b) and (c) above
(f) reduce the load to zero and record the deflection after 2 minutes

Repeat the sequence for each of the remaining load cycles unless failure occurs in the interim.

6.3.3 - If the specimen did not fail during the cyclic test apply the load in a single direction from zero to the highest load reached during the cyclic test at a speed of approximately 1000 N/min. Continue loading and recording as in the static test (Clause 6.2)

6.4 HIGH HUMIDITY OR WATER IMMERSION TESTS

6.4.1 - When testing specimens subjected to high humidity, the specimens shall be first conditioned in an environmental chamber set for the desired relative humidity (e.g. 80 or 100 percent) at a defined temperature (typically 22°C).

6.4.2 - Where an environmental chamber is not available, or where it is preferred, a water immersion test may be substituted.

6.4.3 - In the water immersion test, the specimen shall be immersed flat in a container of water held at 21°C (+1 -1) with a head of 25mm of water over the top surface of the specimen. The specimen shall be blocked so that it is raised off the bottom of the container.

6.4.4 - The specimen shall remain immersed for:
(a) 2 hours where the sheathing is gypsum board
(b) 24 hours where the sheathing is wafer board, plywood or cementitious material

6.4.5 - Upon removal from the water, carefully wipe the surfaces and edges of the specimen and commence load testing immediately.

7. TEST REPORT

7.1 The test report shall include the following information:
(a) date of test and of report
(b) names and addresses of test sponsors and test agency
(c) names of testing personnel
(d) identification of the materials in the specimens (manufacturer, type, source of supply and other pertinent information)
(e) dimensions of test specimen
(f) details of attachment of test specimen in the test fixture
(g) location of loading jacks and dial indicators and description of test equipment
(i) list of observers

(j) photographs of the test assembly and representative specimens (before and after testing) with descriptive captions or text
(k) signatures of responsible persons
(l) all raw data in tabular form
Note: A drawing may be used to show information required by 7.1.(e), 7.1.(f) and 7/.1.(g)

7.2 The test report shall include the following calculations and graphs:
(a) the adjusted loads and corresponding deflections for each tested specimen.
(b) the adjusted average loads and corresponding deflections for each set of tested specimens
Loads and deflections are required to be adjusted from those observed in order to obtain the deflection at the level of the top row of screws with the load applied at the same level.
(c) the shear rigidity
(d) the shear strain
(e) a load - deflection graph for the adjusted average loads and deflections for each set of tested specimens
Note: Where cyclic tests are performed, a graphical representation of the hysteresis peak of the last cycle of each of the first four load increments, and a complete hysteresis curve of the last cycle of the fifth load increment is recommended to be included, in addition to the static load - deflection curve.

7.3 Loads and deflections are required to be adjusted from those observed in order to obtain the deflection at the level of the top row of screws with the load applied at the same level. These adjusted loads and adjusted deflections are calculated as follows:
(a) from the measured dimensions **c**, **d**, **h** and **j**, (Figure 3) determine **e = d-c**; **f = h-c**; and **g = j-c** for each test specimen. (For cyclic load tests determine also $f' = h'-c$; and $g' = j'-c$ for each test specimen.)
(b) calculate the adjusted load $P' = P\ (f/e)$, where **P** is the value of each recorded load for each test specimen.
(c) calculate the adjusted deflection $\Delta' = \Delta(e/g)$ where Δ is the value of the recorded deflection corresponding to each recorded load **P**.
(d) determine the adjusted average loads P'' and corresponding deflections Δ for each set of tested specimens.
($P'' = \Sigma_1^n P'/n$; $\Delta'' = \Sigma_1^n \Delta'/n$ where **n** is the number in a set)

7.4 The shear rigidity and shear strain are calculated from the adjusted average loads and deflections for a set of tested specimens as follows:

(a) shear rigidity $q = 0.8\ P_u''/\Delta_{0.8}''$

where P_u'' = adjusted average ultimate (failure) load

$\Delta_{0.8}''$ = adjusted average deflection corresponding to $0.8\ P_u''$

(b) shear strain $\gamma'' = \Delta_{0.8}''/e$

7.5 Shear rigidity q and shear strain γ shall be converted to limit shear rigidity $\bar{q}_o$ and limit shear strain $\bar{\gamma}_o$ for use in conjunction with CAN/CSA S136.

$\bar{q}_o = q/(2 - s/300)$ where s is the fastener spacing

$\bar{\gamma}_o = \gamma(2 - s/300)$

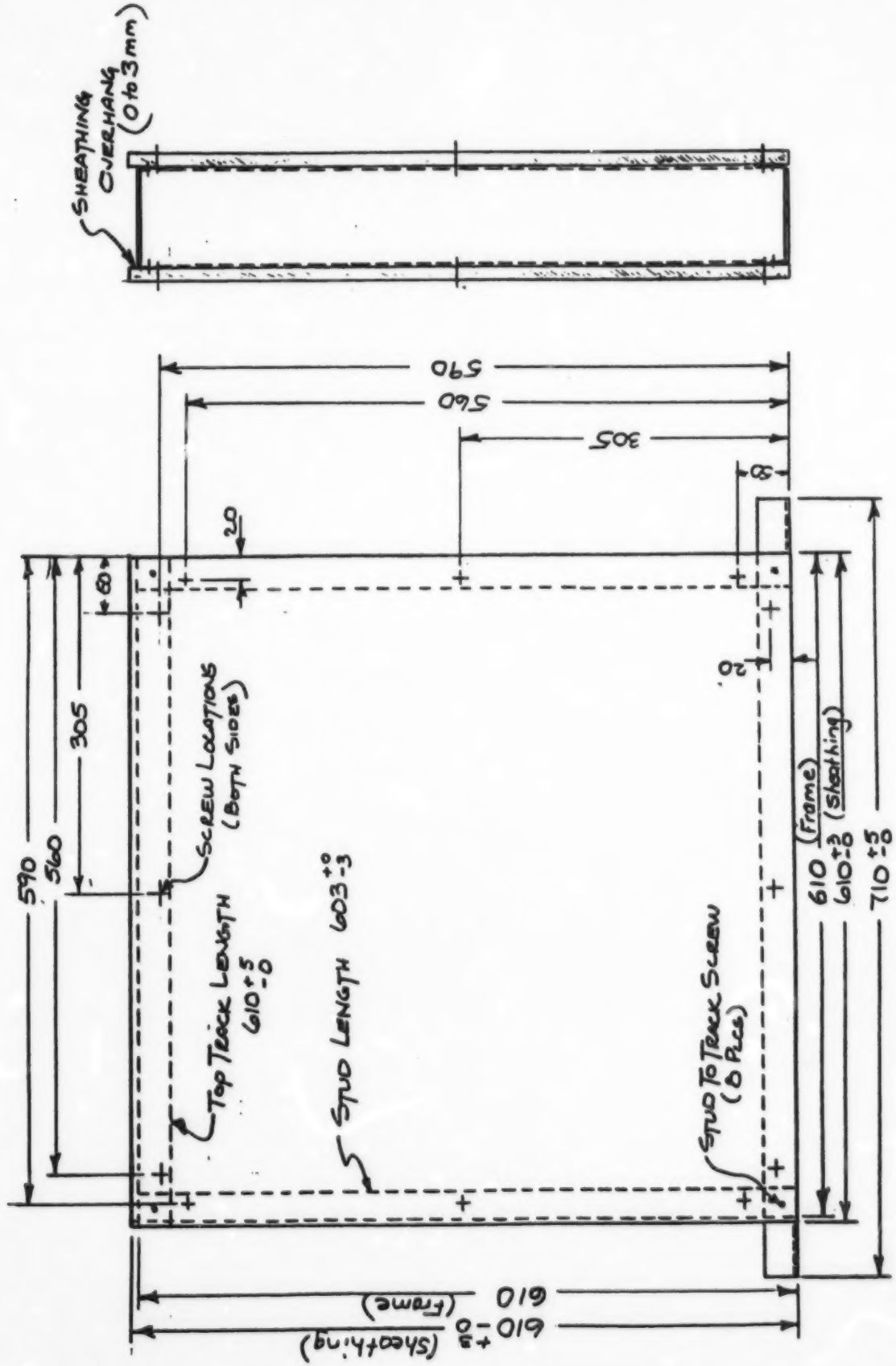

FIGURE 1: SPECIMEN DIMENSIONS (All dimensions in mm)

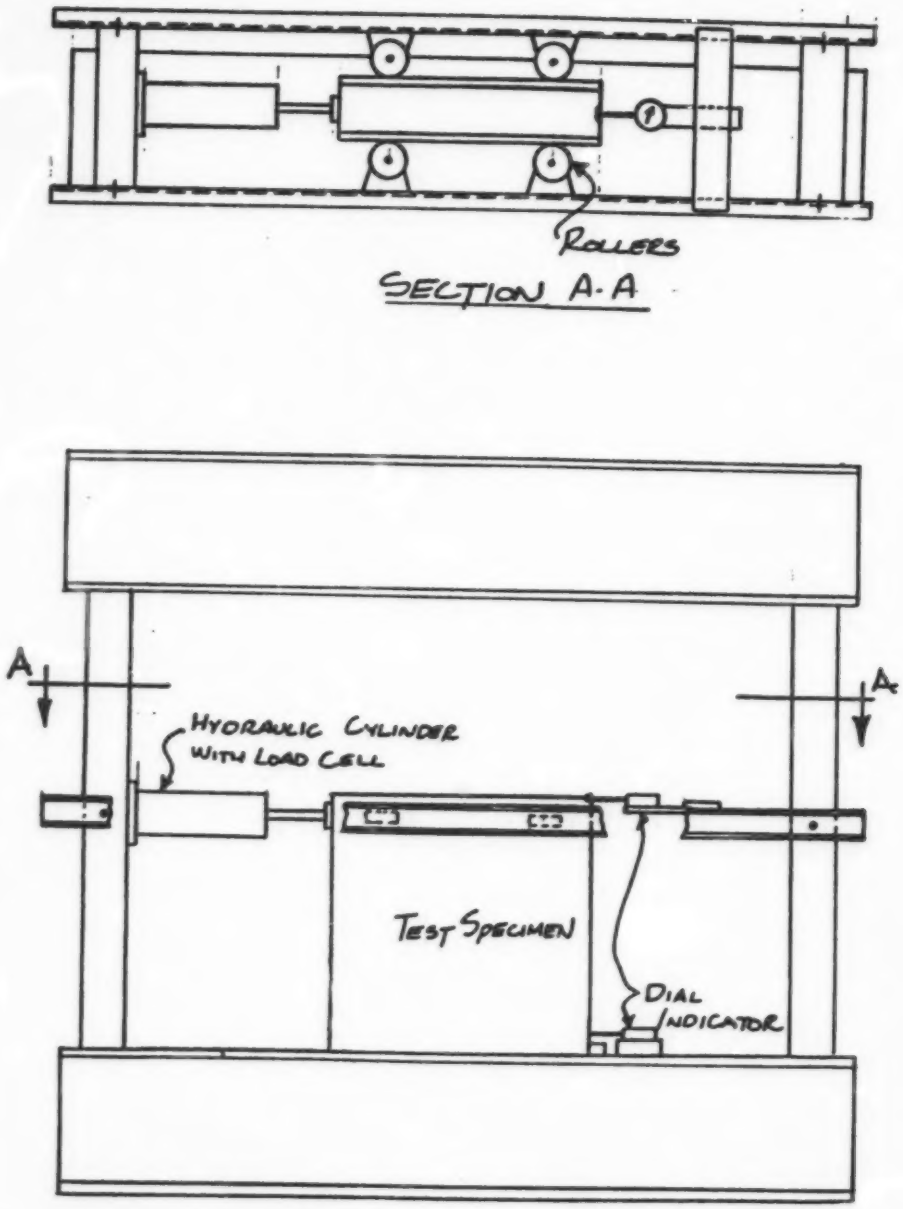

FIGURE 2: TEST FIXTURE WITH MOUNTED SPECIMEN (Uni-Directional Loading)

STATIC LOAD: USE F_1, D_2 & D_4
CYCLIC LOAD: USE F_1 WITH D_2 & D_4
AND F_2 WITH D_1 & D_3

NOTE: Dimensions h' and j' are measured when conducting cyclic load tests

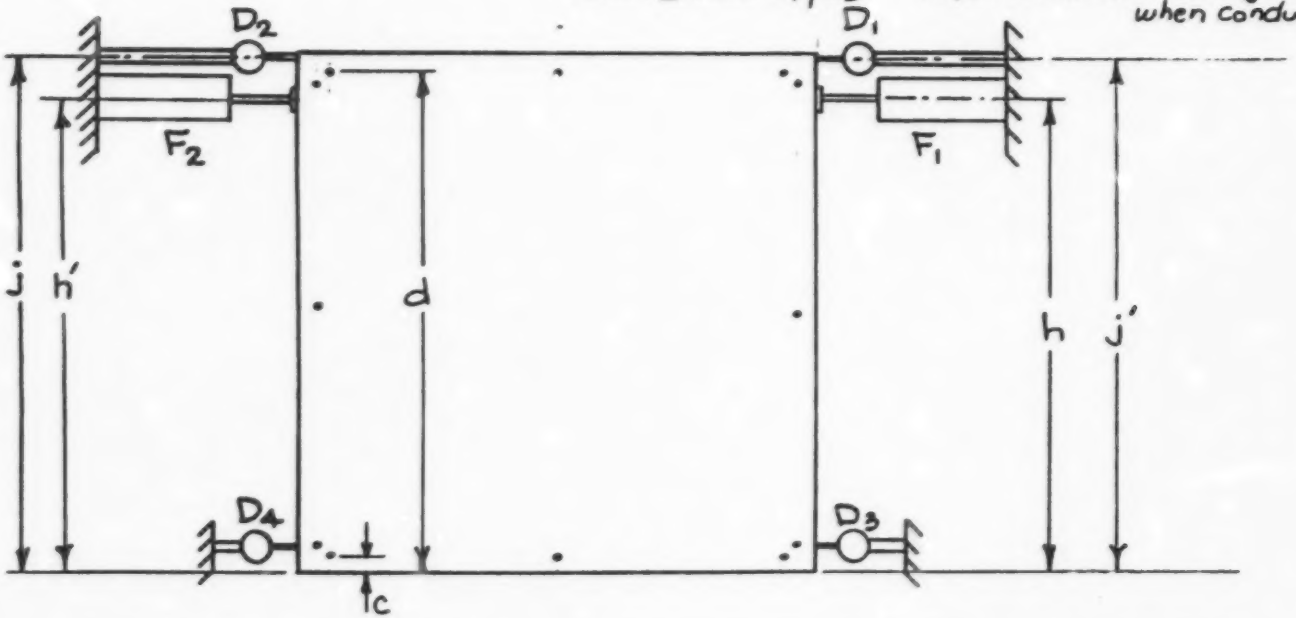

FIGURE 3: INSTRUMENT POSITIONS & TEST MEASUREMENTS

APPENDIX B

6.8.2 Studs in Compression

6.8.2.1

For studs having identical sheathing material (having limit shear rigidity $\overline{Q}$) attached to both flanges, and neglecting any rotational restraint provided by the sheathing, the factored compressive resistance shall be determined by

$C_r = \phi_a A_e F_a$

where

A_e = effective cross-sectional area determined in accordance with Clause 5.6.2, with $f = F_a$

F_a = the least of the following three provisions:

Provision 1
To preclude column buckling between fasteners in the plane of the wall, F_a is determined as in Clause 6.6.1 with KL equal to two times the distance between fasteners.

Provision 2
To preclude flexural or torsional overall column buckling, or both, F_a is determined as follows:

(a) when $F_p > F_y/2$

$$F_a = F_y - \frac{(F_y)^2}{4F_p}$$

(b) when $F_p \leq F_y/2$

$$F_a = F_p$$

where

F_p = critical elastic buckling stress under concentric loading, which shall be taken as specified below for each section type:

(i) for singly symmetric channels, F_p is the lesser of

$$F_p = 0.833(F_{ey} + \bar{Q}_a)$$

$$F_p = \frac{0.833}{2\beta}\left[F_{ex} + F_{t\Omega}) - \sqrt{(F_{ex} + F_{t\Omega})^2 - 4\beta F_{ex}F_{t\Omega}}\right]$$

(ii) for Z-sections, F_p is the lesser of

$$F_p = 0.833\,(F_t + \bar{Q}_t)$$

$$F_p = \frac{0.833}{2}\left[F_{ex} + F_{ey} + \bar{Q}_a) - \sqrt{(F_{ex} + F_{ey} + \bar{Q}_a)^2 - 4(F_{ex}F_{ey} + F_{ex}\bar{Q}_a - F_{exy}{}^2)}\right]$$

(iii) for doubly symmetric I-sections, F_p is the lesser of

$$F_p = 0.833(F_{ey} + \bar{Q}_a)$$

$$F_p = 0.833\,F_{ex}$$

where for items (i), (ii), and (iii)

$$F_{ey} = \pi^2 E/(L/r_y)^2$$

$$F_{ex} = \pi^2 E/(L/r_x)^2$$

$$F_{exy} = \pi^2 E I_{xy}/AL^2$$

$$F_t = \frac{1}{A(r_o)^2}\left[GJ + \frac{\pi^2 E C_w}{L^2}\right]$$

$$F_{t\Omega} = F_t + \bar{Q}_t$$

$\bar{Q}$ = $\bar{q}B$ = limit shear rigidity based on sheathing on both flanges of studs

$\bar{q}$ = limit shear rigidity per unit length of stud spacing with sheathing on both flanges of studs based on actual fastener spacing = $\bar{q}_o(2 - s/300)$ (see Table 6)

B = stud spacing

$$\bar{Q}_a = \frac{\bar{Q}}{A}$$

A = fully effective cross-sectional area of stud

$$\bar{Q}_t = \frac{\bar{Q}d^2}{4A(r_o)^2}$$

$$\beta = 1 - (x_o/r_o)^2$$

x_o = distance from shear centre to centroid of section (absolute value)

$$r_o = \sqrt{(r_x)^2 + (r_y)^2 + (x_o)^2}$$

r_x, r_y = radii of gyration of fully effective cross-sectional area about centroidal principal axes
d = overall depth of section
L = length of stud
I_{xy} = product of inertia of fully effective cross-sectional area

Provision 3

To preclude shear failure of the sheathing, F_a shall also not exceed 0.833σ, where σ is determined (by iteration) to satisfy the requirement that γ, the shear strain in the sheathing corresponding to σ, shall not exceed the limit shear strain of the sheathing, γ, given in Table 6. To initiate the iterative calculations required to establish the strain compatibility of γ and $\bar{\gamma}$, σ should initially be taken as the lesser F_a, as calculated in Clause 6.8.2.1, Provisions 1 and 2. The shear strain, γ, shall be determined as follows:

$$\gamma = \frac{\pi}{L}\left[C_1 + E_1\frac{d}{2}\right]$$

where

C_1 and E_1 are the absolute values of C_1 and E_1 specified for each of the following section types:

a) singly symmetric channels

$$C_1 = \frac{\sigma C_o}{F_{ey} - \sigma + \bar{Q}_a}$$

$$E_1 = \frac{\sigma[(F_{ex} - \sigma)(r_o)^2 E_o - x_o D_o) - \sigma x_o(D_o - x_o E_o)]}{(F_{ex} - \sigma)(r_o)^2(F_{t\Omega} - \sigma) - (\sigma x_o)^2}$$

(b) Z-sections

$$C_1 = \frac{\sigma[C_o(F_{ex} - \sigma) - D_o F_{exy}]}{(F_{ey} - \sigma + \bar{Q}_a)(F_{ex} - \sigma) - (F_{exy})^2}$$

$$E_1 = \frac{\sigma E_o}{F_{t\Omega} - \sigma}$$

(c) I-sections

$$C_1 = \frac{\sigma C_o}{(F_{ey} - \sigma + \bar{Q}_a)}$$

$E_1 = 0$

where for items (a), (b), and (c)

F_{ex}, F_{ey}, F_{exy}, $F_{t\Omega}$, $\bar{Q}_a$, r_o, and x_o are as defined in Provision 2 of Clause 6.8.2.)

C_o, E_o, and D_o are initial column imperfections, which shall be assumed to be at least

C_o = L/350 in a direction parallel to wall
D_o = L/700 in a direction perpendicular to wall
E_o = L/(d x 10 000), a measure of the initial twist of the stud from the ideal configuration

If $\sigma > F_y/2$, then in the definitions for F_{ey}, F_{ex}, F_{exy}, and F_{tQ}, the parameters E and G shall be replaced in Clause 6.8.2.1 (provision 3) by E′ and G′ respectively, given as

$$E' = 4E\sigma(F_y - \sigma)/(F_y)^2$$
$$G' = G(E'/E)$$

For other types of sheathings, $\bar{q}_o$ and $\bar{\gamma}$ may be determined conservatively from representative small-scale tests as described by published, documented methods. Sheathing parameter values $\bar{q}_o$ and $\bar{\gamma}$, determined from representative full-scale tests described by published, documented methods, may also be used instead of the small-scale test values given in Table 6.

Table 6
Sheathing Parameters*

Sheathing Material †	Limit shear rigidity $\bar{q}_o$ ‡, N/mm	Limit shear strain $\bar{\gamma}$, mm/mm
9.5 to 15.9 mm thick gypsum board	525	0.008
Lignocellulosic board	263	0.009
Fibreboard (regular or impregnated)	158	0.007
Fibreboard (heavy impregnated)	315	0.010

**The values given were established from small-scale tests and are subject to the following limitations:*
(a) all values are for sheathing on both sides of the wall assembly; and
(b) all fasteners are No. 6, type S-12, self-drilling drywall screws with pan or bugle head, or equivalent, at 150 to 300 mm spacing.
†All sheathing is 12.7 mm *thick, except as noted.*
‡$\bar{q} = \bar{q}_o(2 - s/300)$
where
s = spacing between fasteners

6.8.2.2

Studs with sheathing on one flange only, unidentical sheathing, or when the rotational restraint is included, or any combination of the above shall be designed in accordance with the same basic principles of analysis used in deriving the provisions in Clause 6.8.2.1.

6.8.3 Combined Axial Load and Bending in Studs

The design strength of studs subjected to combined axial compression and bending shall be determined by

$$\frac{C_f}{C_r} + \frac{M_{fx}}{\left[1 - \frac{C_f}{C'_{rx}}\right] M_{rx}} \leq 1.0$$

When $\frac{C_f}{C_r} \leq 0.15$, the following formula may be used in lieu of the above:

$$\frac{C_f}{C_r} + \frac{M_{fx}}{M_{rx}} \leq 1.0$$

where

C_f = axial compressive load in the stud due to factored loads

C_r = factored compressive resistance under concentric loading according to Clause 6.8.2
M_{fx} = maximum calculated moment about x-axis due to factored loads
M_{rx} = factored moment resistance calculated in accordance with Clause 6.4.1 and 6.4.2
C'_{rx} = $A\,F'_{ex}$
A = fully effective cross-sectional area of member
F'_{ex} = $\pi^2 E/(L/r_x)^2$
L = length of wall stud
r_x = radius of gyration of fully effective cross-sectional area about the x-axis